Expert and Public Perception of Risk from Biotechnology

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Risk perceptions of a series of biotechnology applications were examined in a public (non-expert) sample and an expert sample. Compared with the experts, the public perceived all biotechnology applications as more risky. Both groups perceived food-related applications to be riskier than medical applications. Compared with the public, experts perceived both food and medical applications as less harmful and more useful. Experts also judged the risks posed from medical biotechnology applications as more familiar and acknowledged by people and science. Lay estimates of the risk of food applications were predicted by potential harm, potential benefits, science knowledge, and familiarity; experts' estimates were predicted only by harm and benefits. Lay estimates of the risk of medical applications were predicted by potential harm; experts' estimates were predicted by potential benefits, number and type of people exposed, and science knowledge. We discuss the implications of the results for risk communication about and management of different types of biotechnologies.

KEY WORDS: Affect heuristic; biotechnology; experts; public; risk perception

1. INTRODUCTION

The use of genetically modified organisms (GMOs) in food production as well as in medicine and pharmacology has created much public concern, especially in the 15 member states of the European Union.[1–4] Several risk perception studies have been conducted in the United States and Europe to explore the reasons for public opposition to biotechnology. Some early studies found that the risks of DNA technology were perceived as extremely unknown, with very negative consequences that were delayed in time and not directly observable.[5] In people's minds, DNA technologies were perceived to be very similar to hazards such as nuclear energy, radioactive waste, electromagnetic fields, and other technologies that use rays or chemical substances (e.g., food irradiation and food coloring). DNA manipulation (involving both animal and plant genes) has been judged among the most unknown hazards even when compared to hazards in the food domain (such as bacterial food contamination or food coloring).[6,7]

When the domain of biotechnology and its applications were investigated, other characteristics, besides lack of knowledge, emerged as important in defining public perceptions. People classified biotech applications by their nature (food-related applications vs. medical-pharmaceutical applications),[8,9]4 and by their specificity (those that involved animal

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4 Food-related applications generally apply DNA manipulation to agricultural seeds with the purpose of increasing plant resistance against pests or producing special characteristics in their fruit. The medical/pharmaceutical-related applications apply DNA manipulation on microorganisms to produce therapeutic substances, such as insulin, and study the possibility of producing organs for transplantation through the cloning of human cells or the use of organs of other animals.

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genes vs. those that involved plant genes).[9,10] Genetic modification of animals, for example, was more acceptable if it was applied within a medical context than a food-related context.[9] Applications involving animal genes were rated riskier than applications involving plant genes.[6,10] Frewer *et al.*[10] suggested that people's greater concern toward animal genes could be explained by ethical concerns since negative attitudes toward applications involving animal genes were positively correlated with ethical dimensions (immoral, unnatural, unethical). In this article we examine the difference between food and medical applications because it allows us to understand how the same organism can be judged to have different risk according to the context in which it is embedded.

In Frewer *et al.*'s study,[10] a factor analysis of ratings on 17 self-generated dimensions of risk revealed two major factors describing people's risk perception of biotech applications. The first, accounting for 88% of the variance, was labeled the "rejection factor" and covered personal objections, personal worry, negative welfare effects, creation of inequalities, tampering with nature, and whether the application was immoral, unnatural, unethical, harmful, dangerous, risky, not beneficial, not advantageous, not necessary, not progressive, and not important. The applications involving animal genes obtained more extreme ratings on the negative pole of this factor. The second factor, accounting for 9% of the variance, was represented only by the dimension of "long-term effects," and the most extreme positions on this factor were occupied by medical applications; agricultural applications were perceived to have short-term effects.

1.1. Individual Differences in Risk Perceptions

The present study examines expert and lay people's judgments on a set of dimensions (see Appendix), some of which were previously used in studies adopting the psychometric paradigm[11] and others that were new, such as harm and benefit. The dimensions related to personal and scientific knowledge were also used because they were found to be important in previous studies of biotechnology risk perceptions.[5–7]

Reaction to a hazard is not the same in every person. Individual characteristics, such as past experience with the hazard or specific technical knowledge, can affect the importance of some dimensions and result in quite different judgments of risk. For example, when judging risk, the public sometimes relies on aspects such as catastrophic potential or vividness of the effects, while the experts tend to rely more on observed or expected fatalities.[12–14]

Several studies have documented differences between experts and the public in risk perception,[5,12,15–18] while other studies have not found such differences.[19] This result probably depends on the type of hazard studied. Compared to experts, the public typically gives higher risk estimates to chemical products,[15,16] radioactive waste disposal,[12] nuclear power, police work,[5,17] mountain climbing,[17] warfare, inefficiency of healthcare service, interracial conflicts, shortage of medical equipment,[18] hunting, and spray cans.[5] In addition, the public typically gives lower risk estimates than experts give to electric power, surgery, swimming, X-rays,[5,17] lawn mowers, downhill skiing,[18] and bicycles.[5] Expert and public estimates of the risk derived from oil and gas production tend to be similar.[19]

A recent analysis of nine empirical studies of expert and lay judgments of risk suggested that too many sociodemographic variables confound the ultimate conclusion that experts and lay people really differ in one quality and nature of their risk judgments.[20,21] The present study compared a group of experts, which were people with at least a master's degree and specific training in biology such as university professors or Ph.D. students, with a group of nonexperts, which were individuals without specific training in biology. The expert and nonexpert samples were similar in gender and age.

1.2. Trust in Information Sources

Trust helps us reduce uncertainty to an acceptable level and simplify decisions involving a large amount of information. When we look at consumers' food choices, for example, we discover that they differentiate among brands, retailers, or manufacturers based on how much trust they have in them. For this reason, the less we know about an activity, the more we need to rely on others to make decisions and the more our judgments about risk become a matter of trust. Studies have found that risk perception for genetic engineering is negatively correlated with trust while perception of benefits is positively correlated with trust.[22–25] Trust was found to be indirectly related to acceptance of gene technology.[24] Furthermore, the relationship between risk perception and trust strengthened as knowledge of the activity decreased.[25]

The importance of trust in the negotiation process between the public and the government (experts) has often been noted.[12,26] Trust has been said to be more fundamental to conflict resolution than risk communication.[27] However, trust is fragile. It is created slowly, but can be destroyed instantly. When it comes to winning trust, the playing field is not level: it is tilted toward distrust.[27] Negative (trust destroying) events are more visible or noticeable than positive (trust creating) events. Negative research results were in fact found to be more trusted than positive research results, and this effect was independent of the credibility of the information source.[23] A similar asymmetry between positive and negative research findings was found also in news media coverage of good and bad events.[28]

A survey of the public in 17 European countries showed low trust in national public bodies "to tell the truth about GM crops grown in fields."[29] Probably, European governments paid for mishandling information on BSE meat in the United Kingdom and dioxin contamination of dairy and poultry products in Belgium and the Netherlands. Public opinion does not just respond to technology, but it may actively constrain and influence the development of biotechnology.[2]

Trust may pertain to the overall hazard management process, or it may apply simply to the sources of information. In this case, we talk about "source credibility" and what we investigate is reliability of information. Previous research has indicated that newspapers and TV are among the most trusted sources of information about food-related hazards, followed by medical sources, the government, friends, industry, magazines and radio, university scientists, and consumer organizations. Nevertheless, in the same study, participants were asked to choose the source they would trust the least and newspapers and TV were also more frequently cited as mistrusted sources.[30] High credibility of information source, like trust in risk management, was found to be inversely correlated to risk perception.[31]

In the present study, we investigated source credibility in biotech applications to determine how diverse information sources are trusted with regard to different applications. This issue is important to communication with the public. We also tested the relationship between risk perception and source credibility for specific biotech applications. Based on the literature reviewed above, we expected to find that risk perception would be negatively correlated with source credibility.

2. METHOD

2.1. Sample

A total of 116 persons, 58 experts and 58 nonexperts, took part in the research. Experts were professors or Ph.D. students in biology at a northeastern Italian university; 22 were males and 36 females with a mean age of 30.7 ($SD = 8.74$; ranging from 24 to 72). Nonexperts were people with no specific training in biology; 22 were males and 36 females, with a mean age of 29.7 ($SD = 8.57$; ranging from 21 to 54).

We kept the proportion of males and females and age equal in the two samples. Education level was not controlled. The expert group was highly educated (master's degree or more) while the nonexpert group was "mixed" (some were highly educated but not in biology, but most of them were not highly educated). The nonexpert sample was intended to represent the general public, including a broad range of education levels. The expert sample was recruited by asking professors and Ph.D. students for unpaid participation in our study. The lay sample was recruited by asking the general population of the same city for unpaid participation.

2.2. Material and Procedure

Seven biotech applications served as stimuli in our experiment. All the stimuli were written in Italian. Four were food-related applications: to eat vegetables whose DNA was manipulated with plant genes (FOOD/GMO PLANT), to eat vegetables whose DNA was manipulated with animal genes (FOOD/GMO ANIMAL), to introduce into the environment plants whose DNA was manipulated with genes of other plants (PLANTS/GMO PLANT), and to introduce into the environment plants whose DNA was manipulated with animal genes (PLANTS/GMO ANIMAL). Three were medical-pharmaceutical applications: to use medical substances obtained through the cloning of microorganisms (MEDICAL SUBSTANCES/GMO MICOORGANISM), to use in transplantation organs created from cloning human cells (MEDICAL TRANSPLANT/GMO HUMAN), and to use in transplantation animal organs whose DNA was manipulated in the laboratory (MEDICAL TRANSPLANT/GMO ANIMAL). Also included were two filler items representing potential food hazards (food with pesticides and organically grown food). They served to increase heterogeneity of individual judgment across the scale and control for systematic over- or underuse of the scale by the two groups.

Participants were asked for a risk judgment, reporting to what extent each application was risky for an unspecified individual (state to what extent the following applications are risky for the individual). They were instructed to give their rating on a 0–100 scale, where 0 indicated not at all risky and 100 indicated extremely risky. Each application was then rated on 16 dimensions (see Appendix) on a 1 to 11 scale.

To examine trust in the reliability of an information source, we asked each participant to rate the reliability of information given by a source for each of the applications. Respondents used a 1- to 11-point scale (1 = absolutely not reliable and 11 = extremely reliable). We inquired about four sources of information: (1) national and European Community political organizations (parliament, government, European Commissions), (2) research institutes (National Research Council, CENSIS, National Nutrition Institute), (3) product producer industries and product commerce industries, and (4) environmental groups. Thus, for example, the question relative to FOOD/GMO PLANT and the first source of information was: "To what extent do you think that information about the risk associated with eating vegetables whose DNA was manipulated with plant genes is reliable when it is provided by national and European Community political organizations (Parliament, Government, European Commissions)?"

3. RESULTS

3.1. Factors Predicting Biotech Risk Perception and Expert-Public Differences

For each respondent, the hazards related to food and plants were collapsed into one overall mean judgment labeled "food applications," and the hazards related to medical applications were collapsed into another overall mean judgment labeled "medical applications." This procedure was done for individuals' judgment of risk and for the judgments on the 16 dimensions. This operation had two aims: we sought to test the prediction that judgment of risk differed for food versus medical biotech applications and we needed to reduce the biotech applications to a fewer number of variables to investigate the factors predicting risk perception both in the expert and public sample. This computation resulted in 17 new variables related to food applications and 17 new variables related to medical applications.

Two principal components factor analyses[5] (one for food and one for medical applications) were run on a 116 (subjects) × 16 (dimensions) matrix. The factor analyses were run on the whole sample including the experts and the public and the average factor scores of the subsamples were then compared. Tables I and II present the factor loadings resulting after the Varimax rotation for food and medical applications, respectively. The aim of the two factor analyses was to reduce the 16 dimensions to fewer factors, test the differences between experts and the public on these factors, and examine the factor's explanatory power on the risk estimates.

The analysis relative to food applications revealed a four-factor solution accounting for 71.88% of the total variance. We did not constrain the number of factors to be extracted. The first factor was labeled "harmful and dreaded application" because the dimensions weighing heavily on this component relate to personal and collective exposure, harm to man and to environment, negative consequences, risk for future generations, dread, and involuntary risk. The second factor was labeled "useful application" since the dimensions included in this factor are related to benefits, acceptability of risk, and knowledge of the application. The third factor was called "science knowledge" and the components loading on this factor were related to science knowledge and observability of the damage. The fourth factor was defined by the only dimension of "new"; therefore, it was labeled "new application."

Analysis of the medical applications revealed a five-factor solution accounting for 69.9% of the total variance. We did not constrain the number of factors to be extracted. The first factor was labeled "useful and harmless application" because the dimensions loading on this component related to benefits for man, personal benefits, acceptable risk, low harm to man and the environment, and lack of dread risk. The second factor was named "risk exposure" and included the dimensions personal exposure, collective exposure, and future generations. The third factor was called "new and unknown" because the relevant dimensions related to personal and scientific knowledge and new risk. The fourth factor was related to the

[5] Principal components analysis was preferred over principal factors analysis because in the former all of the variability in each item is used in the analysis, whereas in the latter only the variability in each item that it has in common with the other items is used. We preferred PCA because our aim was data reduction, whereas PFA is used when the goal of the analysis is to detect structure.

Table I. Rotated Factor Matrix of the 16 Dimensions for Biotech Food Applications

	Factor 1: Harmful and Dread Application (31.4% Var.)	Factor 2: Useful Application (21.2% Var.)	Factor 3: Science Knowledge (10.2% Var.)	Factor 4: New Application (9.1% Var.)
Personal exposure	**0.865**	−0.074	−0.161	−0.007
Harmful to environment	**0.800**	−0.385	−0.104	0.137
Collective exposure	**0.793**	−0.128	−0.039	−0.105
Harmful to humans	**0.780**	−0.327	−0.145	0.262
Risky for future generations	**0.775**	−0.205	−0.039	0.320
Severe negative consequences	**0.682**	−0.362	−0.255	0.175
Dread	**0.670**	−0.376	−0.143	0.327
Voluntary exposure	**−0.540**	0.221	0.321	−0.150
Acceptable risk	−0.221	**0.839**	0.101	−0.008
Benefits for humans	−0.309	**0.790**	0.153	−0.170
Personal benefits	−0.252	**0.774**	0.203	−0.250
Benefits for the environment	−0.424	**0.704**	0.086	0.031
Precise personal knowledge	0.059	**0.470**	0.199	−0.462
Observable damage	−0.098	0.108	**0.838**	−0.296
Precise scientific knowledge	−0.306	0.290	**0.740**	0.168
New risk	0.320	−0.090	−0.053	**0.824**

potential negative consequences that might damage the environment and it was labeled "potential damage to environment." The last factor included whether the risk was observable and voluntary and it was called "observable and voluntary risk."

The factor scores from both analyses were used as dependent variables in a multivariate analysis of variance (ANOVA) with *expertise* (experts vs. public) as the independent factor. The expertise factor was significant, $F(9, 104) = 8.31$; $p = 0.00001$. Experts scored lower than the public on the "harmful and dreaded application" factor for food ($M = -0.19$ vs. $M = 0.18$), $F(1, 112) = 4.23$; $p = 0.042$. Experts also scored significantly higher than the public on the "useful application" factor for food ($M = 0.46$ vs. $M = -0.44$), $F(1, 112) = 28.95$; $p = 0.00001$. These differences are

Table II. Rotated Factor Matrix of the Dimensions for Biotech Medical Applications

	Factor 1: Useful and Harmless Application (21.8% Var.)	Factor 2: Risk Exposure (18.1% Var.)	Factor 3: New and Unknown Risk (12.4% Var.)	Factor 4: Potential Damage to Environment (8.9% Var.)	Factor 5: Observable and Voluntary (8.6% Var.)
Benefits for humans	**0.852**	−0.227	−0.143	0.042	0.209
Acceptable risk	**0.798**	−0.107	−0.025	0.026	−0.074
Personal benefits	**0.761**	0.082	−0.118	0.377	0.138
Dread	**−0.631**	0.380	0.427	−0.046	−0.057
Harmful to environment	**−0.596**	0.518	0.181	0.306	−0.046
Harmful to humans	**−0.566**	0.547	0.342	−0.074	−0.116
Personal exposure	−0.073	**0.857**	0.051	0.113	−0.170
Collective exposure	−0.130	**0.842**	−0.135	−0.073	−0.082
Risk for future generations	−0.513	**0.626**	−0.318	−0.013	−0.118
New risk	−0.161	−0.117	**0.750**	0.036	−0.078
Personal knowledge	0.079	−0.086	**−0.679**	0.095	−0.086
Precise scientific knowledge	0.224	−0.178	**−0.501**	0.036	0.442
Benefits for environment	0.040	0.130	0.020	**0.872**	0.028
Severe consequences	−0.248	0.321	0.387	**−0.583**	0.181
Observable damage	0.008	−0.090	−0.082	−0.117	**0.868**
Voluntary exposure	0.207	−0.308	0.271	0.220	**0.487**

consistent with our expectation that experts perceive food applications as less harmful and more useful than the public. Analyses on medical applications showed that compared with the public, experts scored higher on the "useful and harmless application" ($M = 0.29$ vs. $M = -0.28$), $F(1, 112) = 10.52$; $p = 0.002$; and lower on the "new and unknown" factor ($M = -0.42$ vs. $M = 0.41$), $F(1, 112) = 23.37$; $p = 0.0001$. Compared with experts, the public perceive that both the food and medical applications have more harm and less benefit. The public judge the risks posed from medical biotech applications as newer and less acknowledged by the people and by science. No other differences were significant.

Regression analyses were performed separately for the expert and public samples, and for food and medical applications. The full linear regression model was tested (enter method) with the factor scores as the independent variables and the mean risk judgment as the predicted dependent variable.

The regression analysis for experts regarding food applications explained 44% of the variance (adjusted R^2) and revealed a significant contribution of the first two factors: "harmful and dread application" ($\beta = 0.57$; $p = 0.0001$) and "useful application" ($\beta = -0.25$; $p = 0.02$). Experts judged the risk to be high when the food application was judged as harmful, dreaded, and not useful. The same analysis carried out for the public explained 30% of the variance (adjusted R^2), but revealed a significant contribution of all four factors: "harmful and dreaded application" ($\beta = 0.54$; $p = 0.0001$), "useful application" ($\beta = -0.57$; $p = 0.0001$), "science knowledge" ($\beta = -0.41$; $p = 0.001$), and "new risk" ($\beta = -0.27$; $p = 0.031$). The public judged the risk associated with biotech food to be high when the application was perceived as harmful, dreaded, and not useful, as well as new or not well known by science. Compared with the experts, the public seems to have a broader perception (based on a greater number of factors) of the risk associated with food applications, and less variance in their perceptions is explained.

The regression analysis for experts regarding medical applications explained 37% of the variance (adjusted R^2) and revealed a significant contribution of the first three factors: "useful and harmless application" ($\beta = -0.36$; $p = 0.002$), "risk exposure" ($\beta = 0.45$; $p = 0.0001$), and "new and unknown risk" ($\beta = 0.37$; $p = 0.001$). Experts judged the risk from medical applications of biotechnology to be high when they thought the application was not useful and harmful, would expose themselves and many people (included future generations) to risk, and was new and unknown. The same analysis carried out for the public explained 45% of the variance (adjusted R^2) and revealed a significant contribution only of the first factor: "harmful and dread application" ($\beta = -0.70$; $p = 0.0001$). For the public, the risk was judged to be high only when the medical application was perceived to be not useful and harmful. Contrary to the food applications, public perception of medical applications is more defined (based a fewer number of factors) and more variance in perceptions is explained. For experts, the perception of the risk of medical applications is broader and the variance is less well explained than it was for food applications.

Overall, the same factors had different predictive power for the two groups. Scientific knowledge and newness were more important in predicting the public's perception of risk from food applications. In other words, when judging the risk associated with an engineered food, the public is concerned not only with potential harm and potential benefits, but also with how much science knows and how familiar the product is. On the other hand, scientific knowledge and the number and type of individuals exposed to the risk were more important in predicting experts' perception of risk from medical applications. For example, when judging risk associated with a transplantation involving human GMOs, the general public is concerned with how useful and how harmful the application can be, whereas experts also consider factors such as the number of people potentially affected by a mass introduction of the application and how much science knows about the application.

3.2. Expertise and Risk from Food and Medical Applications

To test the difference in risk estimation of biotech applications between experts and the public, the risk judgments on a 0–100 scale of the nine applications (seven biotech applications and two filler items) were used as dependent variables in a multivariate ANOVA with *expertise* (experts vs. public) as the independent factor. The *expertise* factor was significant, $F(9, 91) = 8.07$; $p = 0.0001$. Further analyses revealed that compared with the public, the experts significantly and systematically perceived lower risk for all seven biotech applications (all F-values were significant, ranging from 4.65 to 36.18). The only two items for which the experts and the public gave similar (not significantly different) estimates are the two filler items: pesticides and organic food (Fig. 1).

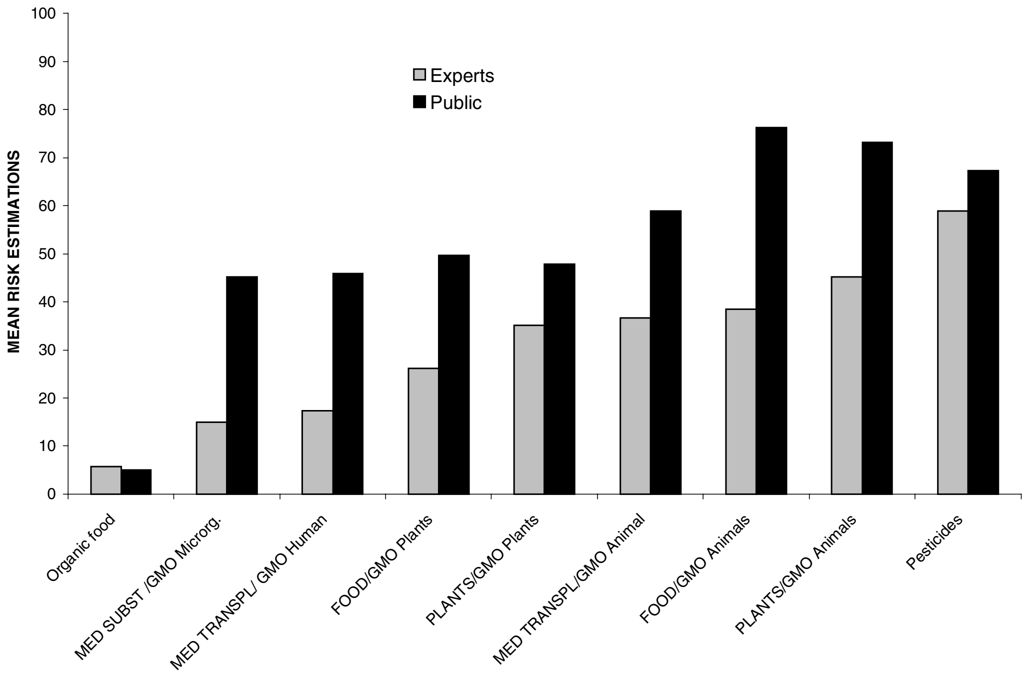

Fig. 1. Mean risk judgments of biotech applications by experts and the public.

To answer the question posed in previous literature about whether food applications are perceived as riskier than medical applications, we carried out a 2 (*expertise*: expert vs. public) $\times$ 2 (*nature* of the application: food vs. medical applications) ANOVA on the mean risk judgment, with the last factor within subjects. Results showed a main effect of the nature of the application, $F(1, 112) = 27.70$; $p = 0.001$, and a main effect of expertise, $F(1, 112) = 44.59$; $p = 0.001$, but no interaction effect, $F < 1$. In support of our hypotheses, the public judged both the risk from food-related applications ($M = 61.75$, $SD = 22.95$) and the risk from medical applications ($M = 50.03$, $SD = 27.79$) higher than did the experts ($M = 35.86$, $SD = 26.77$ and $M = 23.27$, $SD = 18.94$). Both groups judged the risk from food-related applications higher than the risk from medical applications.

To test whether the observed differences in mean risk judgments of food and medical applications among groups can be explained by variations in the quality of perceived risk, we analyzed covariance with the risk factor scores as covariates and *expertise* as the independent variable. The analysis was carried out separately for food and for medical applications. All four risk factors had significant effects (Fs from 5.0 to 45.8) as covariates on the estimate of risk from food biotech applications. Nevertheless, the difference between experts and lay people still remained significant, $F(1, 107) = 5.95$; $p = .016$. Only the first three risk factors had significant effects (Fs from 7.2 to 53.9) as covariates on the estimate of risk from medical biotech applications. Also in this case, the difference between experts and lay people remained significant, $F(1, 107) = 7.47$; $p = 0.007$. These results indicate that the dimensions we used in the present study do not fully explain the difference between experts and the public, although they do make a difference.

We also conducted a 2 (*expertise*: expert vs. public) $\times$ 2 (*nature* of the application: food vs. medical applications) analysis of covariance, introducing "benefits to man" (both those related to food applications and those related to medical applications) as covariates, on the mean risk judgment. The results showed a significant effect of the covariates, $F(1, 110) = 5.39$; $p = 0.022$; $F(1, 110) = 22.77$; $p = 0.001$, which eliminated the significance of the difference between food and medical applications, $F(1, 110) = 3.04$; $p = 0.084$, but not the effect of expertise, $F(1, 110) = 14.85$; $p = 0.001$. According to this result, the difference in risk perception between food and medical applications can be explained by their difference in benefits. However, expertise still had its main effect on risk ratings, apart from benefits.

3.3. Trust in Information Sources

Mean trust in each of the four information sources was computed separately for experts and the public. A 2 (expertise) $\times$ 4 (information source) ANOVA, with the second factor within subjects, was computed on the mean trust ratings. The main effect of expertise was not significant, $F(1, 101) = 2.13$; $p = 0.147$, but there was a significant main effect of source, $F(3, 303) = 53.49$; $p = 0.001$, and a significant interaction of source with expertise, $F(3, 303) = 15.41$; $p = 0.001$. Information provided by research institutes and environmental groups was trusted the most ($M = 6.46$ and $M = 5.85$), followed by political organizations ($M = 4.24$), while information provided by industries was trusted the least ($M = 3.23$). Differences among sources were significant at $p < 0.05$ except the comparison of research institutes with environmental groups. The expert and public samples were found to agree on the trustworthiness of all sources except for environmental groups, which were trusted significantly more by the public than by the experts ($M = 7.42$ and $M = 4.58$), $F(1, 101) = 26.20$; $p = 0.001$.

Correlation coefficients were computed across individuals between trust in information source and risk judgments for the expert and the public samples. We predicted that if people perceived as reliable the information provided by a source (e.g., national and European Community political organ) about the risks associated with a biotech application, then they would perceive the application as low in risk. Therefore, we expected a negative correlation. The relationship, although weak, was generally negative and in line with the prediction and the existing literature. The judgment of risk from FOOD/GMO plants correlated negatively with trust in research institutes in the expert sample ($r = -0.41$; $p < 0.01$) and public sample ($r = -0.30$; $p < 0.05$) and with trust in product producer industries in the expert sample ($r = -0.37$; $p < 0.01$). The judgment of risk from PLANTS/GMO plants correlated negatively with trust in product producer industries in the expert sample ($r = -0.29$; $p < 0.05$). The only positive relationships with risk judgment were found for trust in information provided by environmental groups and risk from FOOD/GMO plants ($r = 0.29$; $p < 0.05$) and FOOD/GMO animal ($r = 0.26$; $p < 0.05$), but only for the expert sample.

3.4. Expert-Public Differences in Benefit-Harm Correlations

Tables III and IV show the mean and correlation coefficients between the dimensions related to harm and benefits to humans and the environment for each application and for the two samples. Harm and benefits were negatively correlated both in the expert and in the public sample. However, the experts think biotech applications have many benefits and cause low harm to humans, whereas the public sees biotech applications as having low benefits and causing high harm to humans. One exception is the benefits and harm to the environment posed by the medical applications, for which both experts and public gave low ratings, resulting in positive correlations (experts) or low correlations (public). Using the Fisher r-to-z transformation and then calculating the value of z, we assessed the significance of the difference between pairs of correlation coefficients in the two independent samples. Eight pairs of correlation coefficients were found to be significantly different from each other.

Table III. Mean Benefits and Harm Judgments for the Expert and the Public Samples

	Experts				Public			
	Benefits to Humans	Harm to Humans	Benefits to Environ.	Harm to Environ.	Benefits to Humans	Harm to Humans	Benefits to Environ.	Harm to Environ.
FOOD/GMO plants	6.86	5.48	4.30	5.79	5.41	6.40	3.79	7.14
FOOD/GMO animals	6.02	6.20	3.73	6.71	3.74	8.19	2.66	8.17
PLANTS/GMO plants	6.96	5.29	5.14	6.30	5.26	6.67	4.00	7.46
PLANTS/GMO animals	6.29	6.45	4.09	7.11	3.33	6.19	2.60	8.43
MED SUBST /GMO μg	8.61	4.39	4.13	4.18	6.43	5.64	3.89	5.41
MED TRANSPL/ GMO human	8.50	3.82	3.51	3.30	7.55	5.57	4.22	4.81
MED TRANSPL/GMO animal	7.86	5.11	3.51	3.72	6.05	6.21	3.77	5.28
Pesticides	4.53	8.71	2.26	9.18	3.61	8.72	2.26	9.24
Organic food	8.05	3.00	8.80	2.66	9.47	2.49	9.80	2.69

Table IV. Correlations Between Benefits and Harm for the Expert and the Public Samples

	Benefits/Harm to Humans			Benefits/Harm to Environment		
	Expert	Public	Difference (z-Value)	Expert	Public	Difference (z-Value)
FOOD/GMO plants	−0.639**	−0.166	−03.06***	−0.354**	−0.375**	n.s.
FOOD/GMO animals	−0.743**	−0.251	−03.62***	−0.547**	−0.506**	n.s.
PLANTS/GMO plants	−0.294*	−0.427**	n.s.	−0.639**	−0.498**	n.s.
PLANTS/GMO animals	−0.604**	−0.320**	−01.89*	−0.695**	−0.484**	−01.70*
MED SUBST /GMO μg	−0.693**	−0.360**	−02.48**	0.193	0.258	n.s.
MED TRANSPL/ GMO human	−0.556**	−0.544**	n.s.	0.372**	−0.011	−2.11*
MED TRANSPL/GMO animal	−0.328*	−0.497**	n.s.	0.442**	−0.204	3.54**
Pesticides	−0.415**	−0.661**	−01.72*	−0.512**	−0.587**	n.s.
Organic food	−0.628**	−0.582**	n.s.	−0.654**	−0.642**	n.s.

$* = p < 0.05$, $** = p < 0.01$, $*** = p < 0.001$.

4. DISCUSSION

When we investigated judgments on 16 dimensions of biotechnology and its applications, four (food domain) and five (medical domain) factors explained most of the variance. The factors that emerged for both food and medical applications were similar and related to the notions of harm and benefits, the number of people exposed, the scientific knowledge, the fact that biotech is a new risk, the potential damage to environment, and the degree to which the consequences were voluntary or observable. The diverse set of dimensions used in the present study affected the factor analytic results. The "rejection factor" found by Frewer *et al.*[10] split into separate factors in our study. No ethical factor emerged since no ethical dimension was used.

We observed several similarities and differences between the expert and public perceptions. The differences in risk perception were both quantitative and qualitative. The relevant results can be summarized as follows:

1. Compared with the public, the experts significantly and systematically perceived less risk for all of the seven biotech applications.
2. Both groups judged the risk from food-related applications higher than the risk from medical applications, in line with previous literature.[10]
3. Compared with the public, the experts perceived food applications as less harmful and more useful.
4. Compared with the public, the experts perceived medical applications as less harmful, more useful, better known to science, and less new.
5. When estimating the risk of biotechnology applied to food, the public was concerned not only with potential harm and potential benefits, but also with how much science knows about it and how new they perceived the product to be, while experts were only concerned with how harmful and useful it is.
6. When estimating the risk of biotechnology applied to the medical domain, the public was concerned with how useful and how harmful the application could be, whereas experts also considered factors such as the number and type of people potentially affected by a mass introduction of the application and how much science knew about the technology.

As previously found for other hazards, experts and the public differ in their perception of risk.[12,15–18] However, experts' and nonexperts' differences may be affected by the nature of the hazard. New and technological hazards, such as biotechnology, might be especially sensitive to the *expertise* factor because of the specialized knowledge surrounding this type of risk. When we tested if the observed differences in perceived risk levels among groups could be explained by variations in the quality of perceived risk, the results indicated that the dimensions we used in the present study did not fully explain the difference between experts and the public, although they did make a difference. Other factors not covered in this study (e.g., ethical factors) might have significantly contributed as well.

With respect to the communication of information related to biotech applications, these results suggest that public perceptions of risk from biotech applications could be reduced by providing information about benefits. On the other hand, experts' perception of risk from biotech applications could be increased by providing information on harmful effects and negative consequences. In both cases, however, the perception of risk should be conveyed by the general affective meaning that the experts and the public attribute to biotechnology.

The mean ratings of trust in information source were as we expected. Information provided by research institutes and environmental groups was trusted the most (especially for the public), followed by political organizations, while information provided by industries was trusted the least. However, we were surprised to find a low correlation between trust in information source and risk perception. This low correlation might be explained by the way we measured trust (as information reliability provided by a source rather than trust in risk management, as has been used in previous studies).

The negative correlations between harm and benefit across most applications for both experts and the public support the idea that people make judgments according to general affective feelings. If their feelings are positive, they will judge an application as high in benefits and low in risk; if their feelings are negative, these judgments will be reversed. Reliance on the affect heuristic may be producing the negative correlations observed in judgments of biotechnologies. Interestingly, several of the negative correlation coefficients were significantly larger for experts than the public. One explanation for this result is that compared with the public, experts are relying more on affect when judging harm and benefit. However, we would not expect experts to rely more on affect because they have significant technical knowledge to rely on. A more likely explanation is that the nature of the benefits and risks of the applications considered in this study are negatively correlated: the benefit may be saving lives or improving health and the risk is losing lives or hurting health. Experts know this well and thus show stronger negative correlations. Furthermore, public judgments about benefits and harm from biotech applications may be less reliable, thus resulting in smaller inverse correlations.

A final comment relates to the dread dimension, which weighed heavily on the first factor in both samples. Dread measures the emotional reaction (negative) when thinking about a hazard. Several studies and theories are reconsidering the direct role (not mediated by cognition) of affect in judgment and decision making.[32–34] Our data further support this consideration and show how risk from biotech applications can be linked to the dread, affective reaction, both in experts and the public.

APPENDIX: RISK DIMENSIONS

1. Dread: How much does this application frighten you? (1 = not at all; 11 = very much)
2. New: Is it a new risk or an old and familiar risk? (1 = absolutely old; 11 = absolutely new)
3. Voluntary extent of exposure to risk: To what extent people can decide to voluntarily expose himself/herself to the risk? (1 = exposure is involuntary; 11 = exposure is voluntary)
4. Personal exposure to the risk: How much you think you are personally exposed to the potential risk derived from this application? (1 = not at all exposed; 11 = completely exposed)
5. Collective exposure to the risk: How many people in the world are exposed to these risks? (1 = very few people; 11 = many people)
6. Observability of the damage: To what extent is the potential damage produced by the application observable? (1 = absolutely not observable; 11 = definitely observable)
7. Severity of negative consequences: How severe are the potential negative consequences of this application? (1 = not at all severe; 11 = extremely severe)
8. Risk for future generations: To what extent does it pose a risk to future generations? (1 = risk is very low; 11 = risk is very high)
9. Personal knowledge of the risk: How precise is your personal knowledge of the risk associated with this practice? (1 = absolutely not precise; 11 = extremely precise)
10. Scientific knowledge of the risk: How precise is scientific knowledge of the risk associated with this application? (1 = definite low knowledge; 11 = very high knowledge)
11. Benefits for humans: To what extent will humans benefit from this application? (1 = no benefits at all; 11 = many benefits)
12. Personal benefits: To what extent will you personally benefit from this application? (1 = no benefits at all; 11 = many benefits)
13. Benefits for the environment: To what extent will the environment benefit from this

application? (1 = no benefits at all; 11 = many benefits)

14. Harm to humans: How much harm will derive from this application to humans? (1 = no harm at all; 11 = very much harm)
15. Harm to environment: How much harm will derive from this application to the environment? (1 = no harm at all; 11 = very much harm)
16. Risk acceptability: To what extent do you think the risks associated with this application are acceptable to obtain the benefits? (1 = not acceptable at all; 11 = definitely acceptable)

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